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Natural Regeneration 10 Years After a Douglas-Fir Tussock Moth Outbreak in Northeastern Oregon

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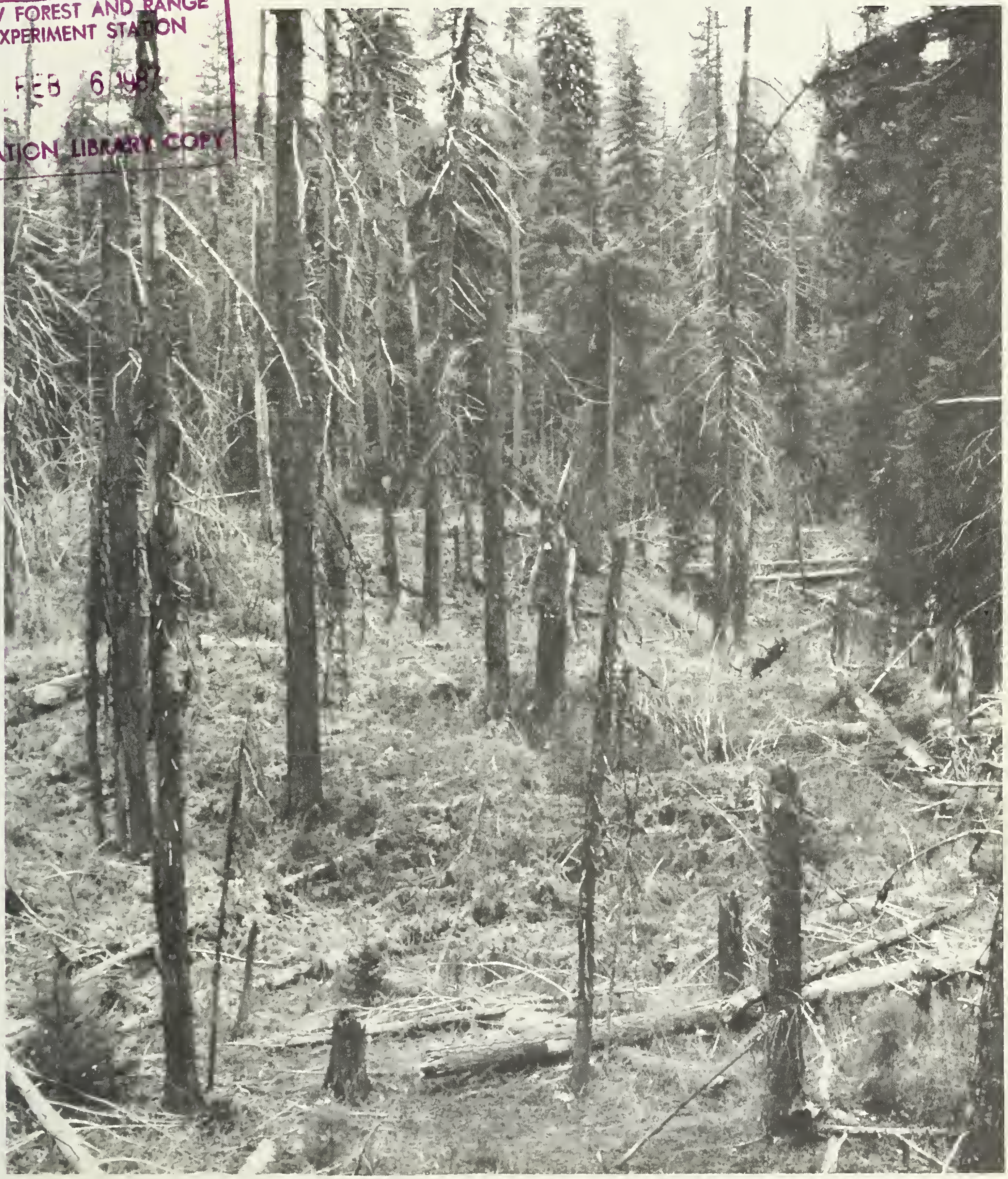

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Abstract

Wickman, B.E.; Seidel, K.W.; Starr, G. Lynn. Natural regeneration 10 years after a Douglas-fir tussock moth outbreak in northeastern Oregon. Res. Pap. PNW-RP-370. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; **1986.** 15 p.

A survey of natural regeneration 10 years after severe grand fir mortality caused by an outbreak of Douglas-fir tussock moth was conducted in the Wenaha-Tucannon Wilderness in the Blue Mountains of northeastern Oregon. Seedling stocking was only moderate, but seedling density was adequate where present. Grand fir is dominating both preoutbreak and postoutbreak regeneration, but ponderosa pine has increased substantially over preoutbreak levels. The largest seedlings are larch, spruce, and pine. These species have the fastest juvenile growth rate and also were not severely defoliated during the outbreak. Certain environmental factors affecting regeneration did not produce strong correlations other than some obvious relations like distance to nearest seed tree. There was a weak positive relation of regeneration density with the presence of litter. Given the past and present management regimes for this area, the pattern of gradual stand dominance by grand fir is the result of natural succession and lack of ground fires. Within a hundred years, history will probably repeat itself with a severe tussock moth outbreak that again reduces the grand fir component of the stand.

Keywords: Regeneration (stand), Douglas-fir tussock moth, *Orgyia pseudotsugata,* grand fir, *Abies grandis,* regeneration (natural), mixed stands, Blue Mountains-Oregon, Oregon (Blue Mountains), insect damage-forest.

Summary

Natural regeneration was surveyed 10 years after severe grand fir mortality caused by an outbreak of the Douglas-fir tussock moth in the Blue Mountains of northeastern Oregon. The study plots were located in the Wenaha-Tucannon Wilderness. Management influences have been limited to grazing cattle and excluding fire since the early 1900's. Regeneration measurements were made in a 350-acre mixed conifer stand that suffered 40-75 percent grand fir mortality immediately after the outbreak. Plots for measuring tree damage were established in 1972; the regeneration plots were located in and adjacent to these older plots.

Based on the percentage of 4-milacre subplots stocked, and on the average number of seedlings per acre for all species and ages, regeneration was moderate. There were 572 seedlings per acre and 496 were in the postoutbreak class. Sixty percent of the 4-milacre subplots were stocked with at least one seedling of any age and 54 percent were stocked with seedlings of postoutbreak age. Regeneration establishment since the outbreak has been spotty. Depending on the definition of adequate stocking, the proportion of plots successfully regenerated can be determined. If 60-percent stocking of 4-milacre subplots is considered satisfactory, then only half the plots met this criteria and the area as a whole is understocked. On the basis of seedling density, however, 67 percent of the subplots had at least 400 trees per acre and understocking is not a problem.

Grand fir, ponderosa pine, Douglas-fir, and Engelmann spruce were the most common species in that order. Stocking of ponderosa pine in the postoutbreak regeneration was 19.7 percent compared to a preoutbreak level of 0.7 percent. Douglas-fir stocking has also increased in the postoutbreak regeneration.

Species dominance has changed in the postoutbreak regeneration. Ponderosa pine has increased from 2 seedlings per acre prior to the outbreak to 92 per acre currently. The tallest or fastest growing species, during the postoutbreak period, are the nonhost Engelmann spruce, larch, and ponderosa pine in that order.

Simple correlation analyses of environmental factors affecting regeneration determined logical biological relations. For example, crown closure showed a significant positive correlation to density of grand fir and Douglas-fir regeneration, thereby reflecting the shade tolerance of these species. An unexpected relationship was the positive correlation between litter and density of regeneration. Exposed mineral soil is generally the most favorable seedbed, although true fir seedlings can become established in light to medium litter layers.

Long-term fire prevention policies have allowed natural succession to result in stand dominance by grand fir. The prevalence of this species will probably result in periodic tussock moth outbreaks.

Introduction

Beginning in 1972 and continuing into 1974, an extensive and severe outbreak of Douglas-fir tussock moth (*Orgyia pseudotsugata* McD.) (DFTM) occurred in the Blue Mountains of Oregon and Washington. Defoliation varied from barely visible to total loss of needles from the host trees—grand fir, *Abies grandis* (Dougl. ex D. Don) Lindl., and Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco. Most of the severe defoliation (greater than 75 percent of the crown defoliated) occurred in patches varying from a few to several hundred acres. Severe defoliation resulted in patches of almost complete host-tree mortality (Wickman 1978a).

Forest managers feared that natural regeneration would not be adequate to reforest the larger patch kills of grand fir and Douglas-fir and consequently planted many of the areas after clearcut and partial cut salvage logging (Seidel and Head 1983). After the outbreak there were also questions about adequacy, timing, and species of natural regeneration and on environmental factors responsible for success or failure of regeneration establishment.

The status of regeneration and factors affecting establishment of seedlings on partial cuts several years after the tussock moth outbreak are reported by Seidel and Head (1983). They found that partial cuts in the mixed conifer/pinegrass community had considerably fewer seedlings than partial cuts in the grand fir/big huckleberry community which were well stocked. Much of the understocking in the mixed conifer stands was apparently related to low and irregular overstory density, lack of advance reproduction, reproduction destroyed by logging, and heavy grass cover.

Heavy grand fir mortality after tussock moth defoliation in a mixed-conifer stand in the Wenaha-Tucannon Wilderness, Umatilla National Forest, offered the opportunity to survey natural regeneration on an unmanaged site. This area represents only one of several habitat types found in the Blue Mountains, but it was one of the most common types in the DFTM outbreak. There are many other elevation gradients and physiographic sites that suffered severe tree mortality. This area was chosen because it was undisturbed by logging, because defoliation and tree damage data were available, and because it is a good growing site that would qualify for intensive timber management in nonwilderness situations. We wanted to

evaluate the status of natural regeneration and the factors affecting its establishment 10 years after the peak of tree mortality in 1973. This paper reports the results of that study.

Objectives

The purpose of the study was (1) to quantitatively evaluate natural regeneration in an undisturbed stand severely damaged by DFTM in 1972 and 1973, (2) to evaluate the condition of the residual overstory at the end of the 10-year period, and (3) to identify environmental factors related to success or failure of regeneration establishment.

Specific objectives were (1) to estimate success of regeneration in terms of stocking percentage and density (number per acre); (2) to determine species composition of the regeneration; (3) to measure regeneration stocking of preoutbreak (advance) and postoutbreak (subsequent) origin and height of each class; (4) to examine the relations between regeneration establishment and several measurable environmental variables such as overstory density, nearest seed source, and understory vegetation; and (5) to measure survival and condition of the residual overstory.

Study Area

The study area, Grizzly Bear Ridge, is in a mixed-conifer forest type in the Wenaha-Tucannon Wilderness of the Blue Mountains of northeastern Oregon at 4,000-4,350 feet elevation (fig. 1). The ridge, a broad plateau, slopes gently to the edge of the Wenaha River canyon "breaks" with a slight southern exposure. It is bisected by a series of deep (20-30 feet), narrow draws, some of which contain

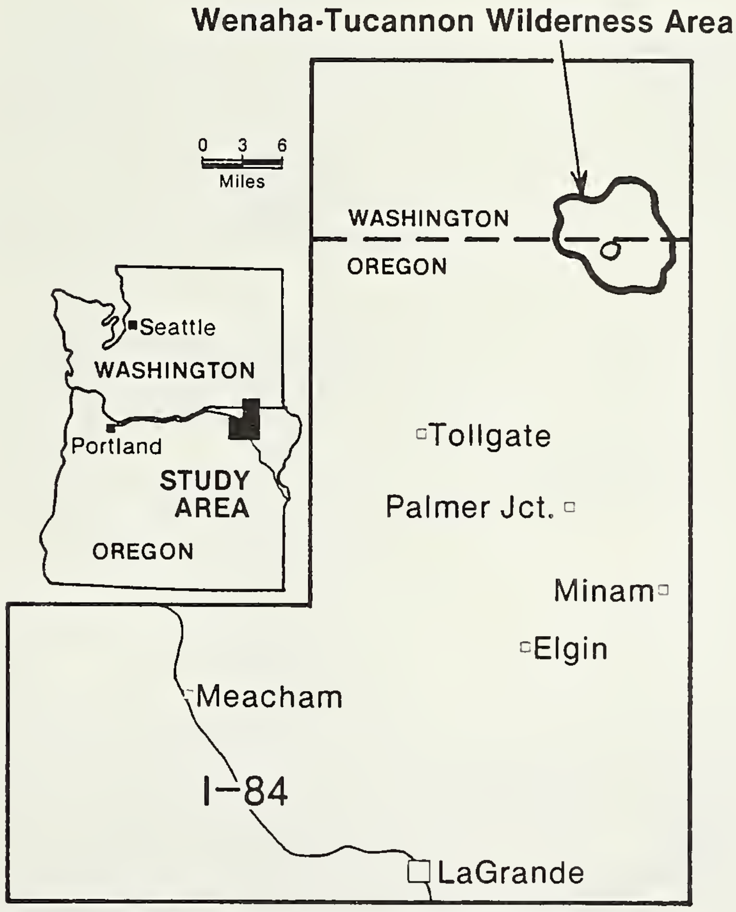

Figure 1—Location of regeneration survey in Wenaha-Tucannon Wilderness, northeastern Oregon.

springs or running water. The habitat type of the stand is *Abies grandis-Pachistima myrsinites,* larch type.[1/] Preoutbreak vegetation was dominated by an overstory of grand fir and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) with a scattering of western larch (*Larix occidentalis* Nutt.) and Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) and very few Douglas-fir. Most of the plateau (about 350 acres) was severely defoliated by tussock moth in 1972 with little additional defoliation noted in 1973. Host-tree mortality continued from 1973 to 1975 and totaled 40-75 percent (Wickman 1978a). Many of the snags resulting from this mortality have fallen and have created a heavy ground cover of logs and branches on some plots. This is also the location of a series of tree damage plots that were established in 1972 to study the effects of tussock moth outbreaks (Wickman 1978a). Some characteristics of the area sampled are given in table 1.

[1/]Identification of the plant community is based on the dominant tree overstory and on shrubs, forbs, and grasses in the understory. This habitat type was classified by S. Conrade Head in 1974. Final Report, Douglas-Fir Tussock Moth Program, on file at the Forestry and Range Sciences Laboratory, Route 2, Box 2315, La Grande, OR 97850.

Table 1—Means and ranges of plot characteristics in heavy tree mortality area, Wenaha-Tucannon Wilderness

Characteristic	Unit of measurement	18 plots	
		Mean	Range of plot means
Elevation	Feet	4,200	4,000-4,350
Aspect	Class	6	3-11
Slope	Class	.2	0-1.0
Residual living overstory:			
Trees per acre	Number	151	47-344
D.b.h.	Inches	7.7	5.0-11.2
Basal area	Square feet per acre	100	18-306
Canopy closure	Percent	15.2	0-38.8
Residual dead overstory:			
Trees per acre	Number	118	78-163
D.b.h.	Inches	12.3	9.2-17.8
Basal area	Square feet per acre	142	76-265
Seedbed:			
Litter	Percent	13.3	1.3-30.0
Logs	Percent	12.5	2.5-22.4
Litter + logs	Percent	25.6	6.3-45.0
Understory vegetation (subplots dominated by):			
Grass	Percent	26.8	
Herbage	Percent	39.2	
Woody perennial	Percent	32.4	
Total ground cover		67.4	61.9-80.0

Methods

Methodology for this study was similar to studies of regeneration in clearcuts in southwestern Oregon (Stein 1981) and in the Blue Mountains of eastern Oregon (Seidel 1979a, Seidel and Head 1983), and in shelterwood cuttings along the east side of the Cascade Range in Oregon (Seidel 1979b). Natural regeneration establishment following a small but severe DFTM outbreak in northern California was reported by Wickman (1978b). In that study it was found that white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.) regeneration on the entire area 10 years after the outbreak was equal to preoutbreak levels. No measurements of regeneration were made, however, in the patches of dead trees.

Sample Selection

Regeneration sample plots were systematically located off a trail running north-south on the west half of the severely damaged stand on Grizzly Bear Ridge. Reconnaissance indicated that stand conditions were homogeneous on the plateau, but the east half was time consuming to reach because of its distance from the trail and difficult access through downed snags. Starting points for the first two regeneration sample plots were determined by the locations of two clusters of 0.02-acre plots used for determining stand damage from 1973 to 1977. The configuration of these plot clusters is described in Wickman (1978a). Sixteen additional plots to survey regeneration were systematically located to the east and north of the older study plots; the plots were never closer than 600 feet and were usually about 1,200 feet apart. Nine plots were sampled in July 1983 and an additional nine plots were sampled in July 1984.

Data Collection

Each plot was approximately 3.6 acres. A grid of 16 sample points (subplots) was located by hand compass and by pacing within each plot. Circular, 4-milacre subplots were systematically spaced at 99-foot intervals on four parallel lines 99 feet apart. Each line contained four subplots. At each sample point, subplots were examined for presence of regeneration, condition of residual overstory, understory cover, and associated environmental variables. A sample point was relocated by moving 99 feet along the line if conditions making it unsuitable for regeneration—streambeds, marshy ground, solid rock—occurred on more than one-half of a 4-milacre subplot.

On each 4-milacre subplot the total number of seedlings and saplings less than 2 inches in diameter at breast height (d.b.h.) was counted and recorded by species, age, and current condition. Regeneration was measured to the nearest centimeter for height and classed as advance (preoutbreak) if 11 years or older (12 years in the 1984 samples) and subsequent (postoutbreak) if 10 years or younger (11 years in the 1984 samples) by counting whorls.

Dominant type of understory vegetation cover (grass, herbaceous, and woody perennials) was noted for each 4-milacre subplot.

A concentric 0.02-acre circular plot was also established at each sample point to determine residual overstory condition. On each of these plots, tree species and d.b.h. were tallied for all standing overstory trees, including trees that died during the regeneration period. Windthrown trees and trees that died and fell during the regeneration period were also counted. The following environmental factors associated with each 4-milacre subplot were observed and recorded:[2/] aspect, slope, litter, litter and logs, canopy closure, ground cover, and dominant ground cover.

[2/] See appendix for details of procedures for measuring and coding the environmental factors.

Data Analysis

To illustrate the status of reforestation, we summarized data in tables showing the percentage of regeneration stocking and the density level of 4-milacre subplots by species and origin (preoutbreak or postoutbreak). Stocking data were summed and the means and standard errors calculated to ascertain current status of regeneration on a per-acre basis.[3]

To determine the relationship between regeneration and environmental variables, correlation coefficients between dependent and independent variables were calculated. Dependent variables (Y) were stocking percentages of 4-milacre subplots and number of seedlings per acre of the various species. Independent variables (X) were the environmental factors listed in the appendix.

Results and Discussion

Regeneration Stocking and Density

Based on the percentage of 4-milacre subplots stocked and average seedling numbers per acre for all species and ages, regeneration was moderate.[4] There were 572 seedlings per acre and most of these (496 seedlings per acre) were in the postoutbreak age class (table 2). Sixty percent of the 4-milacre subplots were stocked with at least one seedling of any age, and 54 percent were stocked with postoutbreak-aged seedlings. In 1972 and 1973 there was high mortality of regeneration due to defoliation (Wickman 1978a) and the pattern of stocking by age class reflects this situation. Furthermore the postoutbreak regeneration distribution was clumpy and highly dependent on proximity of seed trees. Most of the seedlings apparently became established 2 or 3 years after the outbreak-caused mortality as evidenced by the age of current stocking.

The individual plot averages of seedling density and stocking indicate that regeneration establishment since the tussock moth outbreak has been spotty; some acres are not well stocked and others contain clumps of seedlings. Plots were grouped by the number and percentage that attained specific levels of stocking or density to get a better picture of the status of regeneration (table 3). All but one plot had at least 200 trees per acre, and 67 percent of the plots contained 400 or more trees per acre.

Depending on the definition of adequate stocking, the proportion of plots successfully regenerated can be determined. If 60-percent stocking of 4-milacre subplots is considered satisfactory, then only half the plots met this criterion and the area as a whole is understocked. On the basis of seedling density, however, 67 percent of the plots had at least 400 trees per acre and understocking was not a problem.

Species Composition of Regeneration

Grand fir, ponderosa pine, Douglas-fir, and Engelmann spruce were the most common species in that order (table 4). Western larch was found on 2.8 percent of the subplots and did not appear to be an important component of the regeneration. Stocking of ponderosa pine (a nonhost species) in the postoutbreak regeneration was 19.7 percent compared to the preoutbreak level of 0.7 percent. This species is apparently regenerating better after heavy grand fir mortality and may become a more important component of the future stand. Douglas-fir was also a rare species before the outbreak but now is found on 13 percent of the subplots.

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[3]Subplots were considered stocked if they contained at least one seedling.

[4]Stocking classes, as defined by the Pacific Northwest Seeding and Planting Committee (Reynolds and others 1953): well stocked, 70-100 percent; moderately stocked, 40-69; poorly stocked, 10-39; and nonstocked, 0-9.

Table 2—Average stocking percent and number of seedlings per acre of all species in heavy tree mortality area, by regeneration class, Wenaha-Tucannon Wilderness 1/

Regeneration class	Number of plots	Mean + SE 2/	Range
		Stocking percent	
Preoutbreak	18	17.6 ± 2.6	0-37.5
Postoutbreak	18	54.1 ± 3.1	25-75.0
Any age	18	60.2 ± 3.1	37.5-87.5
		Number of seedlings	
Preoutbreak	18	76 ± 15	0-219
Postoutbreak	18	496 ± 76	94-1,359
Any age	18	572 ± 76	141-1,406

1/ Based on 4-milacre plots.

2/ SE = standard error.

Table 3—Proportion of plots stocked at various levels with preoutbreak and postoutbreak regeneration in a heavy tree mortality area, Wenaha-Tucannon Wilderness

Stocking			Trees per acre		
Minimum percent	Number of plots	Percent of total	Minimum number	Number of plots	Percent of total
20	18	100	200	17	94
40	17	94	400	12	67
60	9	50	600	8	44
80	2	11	800	4	22
			1,000	1	6
			1,200	1	6
			1,400	1	6

Table 4—Average stocking of preoutbreak and postoutbreak regeneration, by species, in a heavy tree mortality area, Wenaha-Tucannon Wilderness

Regeneration class	Grand fir	Douglas-fir	Ponderosa pine	Western larch	Engelmann spruce	All species 1/
			Stocking percent ± SE 2/			
Preoutbreak	14.2 ± 2.6	1.4 ± 0.6	0.7 ± 0.7	0.7 ± 0.5	2.3 ± 1.0	17.6 ± 2.6
Postoutbreak	39.8 ± 2.8	11.7 ± 2.0	19.7 ± 3.2	2.5 ± .7	7.9 ± 1.8	54.1 ± 3.1
Any age	47.2 ± 2.4	13.1 ± 2.2	20.4 ± 3.5	2.8 ± .8	8.9 ± 1.8	60.2 ± 3.1

1/ Totals not additive as more than one species or age class can occur on a subplot.

2/ SE = standard error.

Dominant Species

In addition to regeneration estimates based on measurements of seedling stocking and density, the species and age of the largest or most vigorous seedling on each stocked 4-milacre subplot were recorded. These data provide insight to potential species dominance in the future stand. Preoutbreak or oldest seedlings were dominant on about one-quarter of the stocked subplots; the seedlings were primarily grand fir and Engelmann spruce (table 5).

Stocking of preoutbreak grand fir is lower than it might be because of mortality from defoliation in 1972-73. Seedlings originating after the outbreak were dominant on about three-quarters of the stocked subplots. The most dramatic change since the outbreak is the increasing dominance of ponderosa pine.

Another way of looking at importance of species in the developing stand is to compare the number of seedlings per acre by species and age class. When examined this way, grand fir appears to dominate the developing stand in the preoutbreak age class (59 trees per acre) and in the postoutbreak class and at all ages (305 and 364 trees per acre, respectively) (table 6). Ponderosa pine seedlings have greatly increased since the outbreak from 2 per acre prior to the outbreak to 92 per acre currently, indicating that pine may be assuming a greater importance in future stand composition.

Seedling height is a third way of examining dominance. The tallest average regeneration of any age class is Engelmann spruce (64 inches) followed by western larch (61 inches)—both nonhost species (table 7). The tallest seedlings after the outbreak are spruce, larch, and pine; they have the greatest juvenile height growth rates and are also nonhost species.

Relation of Stocking and Density to Environmental Factors

For an assessment of the influence of observed environmental variables on density and stocking of regeneration and their relative importance, correlation coefficients were computed between each environmental variable and stocking percent and density of regeneration. The results of these analyses are presented in tables 8 and 9.

The effects that these variables have on stocking and density of regeneration depend on the species and origin of reproduction. The effect of most variables is logical and has a reasonable biological explanation. For example, crown closure showed a significant positive correlation to density of grand fir and Douglas-fir regeneration; both stocking and density of western larch regeneration were negatively correlated to overstory basal area, overstory trees per acre, or crown closure (tables 8 and 9). This relationship reflects the shade-tolerant nature of larch, which requires greater overstory disturbance for successful regeneration compared to the more shade-tolerant true fir.

Another logical relationship is the significant negative correlation between distance to seed trees and regeneration; in other words, regeneration tends to decrease as the distance to seed trees increases. We expected such a relationship because seed source in a natural regeneration setting is crucial.

Table 5—Seedling dominance, by species and age class, in a heavy tree mortality area, Wenaha-Tucannon Wilderness

Regeneration class	Grand fir	Douglas-fir	Ponderosa pine	Western larch	Engelmann spruce	All species
			Percent			
Preoutbreak	17	2	1	2	4	26
Postoutbreak	44	7	17	1	5	74
Any age	61	9	18	3	9	100

Table 6—Number of seedlings per acre, by species and age class, in a heavy tree mortality area, Wenaha-Tucannon Wilderness

Regeneration class	Grand Fir	Douglas-fir	Ponderosa pine	Western larch	Engelmann spruce	All species
Preoutbreak	59 ± 14	4 ± 2	2 ± 2	2 ± 1	9 ± 4	76 ± 15
Postoutbreak	305 ± 60	62 ± 13	90 ± 17	8 ± 3	31 ± 12	496 ± 76
Any age	364 ± 60	66 ± 13	92 ± 18	10 ± 3	40 ± 16	572 ± 76

Table 7—Average seedling height in a heavy tree mortality area, Wenaha-Tucannon Wilderness

Regeneration class	Grand fir	Douglas-fir	Ponderosa pine	Western larch	Engelmann spruce	All species
			Inches ± SE 1/			
Preoutbreak	44 ± 4	41 ± 13	25 ± 0	61 ± 2	64 ± 7	47 ± 4
Postoutbreak	15 ± 2	9 ± 3	20 ± 4	23 ± 9	26 ± 6	15 ± 2

1/ SE = standard error.

An unexpected relationship was the positive correlation between litter and density of regeneration because exposed mineral soil is the most favorable seedbed, although true fir seedlings can become established in light to medium litter layers (0.25 to 0.5 inch deep).

Observations on the plots indicated that ground cover, especially grasses and bracken fern, appeared to have a detrimental effect on seedling establishment since the outbreak. We found that grand fir in particular and even all species combined were hindered mostly by grass (table 10). This was also noted by Seidel and Head (1983) in partial cuts in the Blue Mountains following the DFTM outbreak. Correlation analyses were negative for ground cover as a whole only for western larch (tables 8 and 9).

Table 8—Significant correlation coefficients (r) between environmental variables and density of regeneration, Wenaha-Tucannon Wilderness[1/]

Species and age class	Aspect	Slope	Basal area	Trees per acre	Crown closure	Ground cover	Litter	Logs	Litter and logs	Distance to seed tree
All regeneration:	-0.37				0.50*		0.63**		0.51*	-0.40*
Grand fir	- .35		0.34		.53*		.62**		.51*	- .43*
Douglas-fir			.67**	0.61**	.69**		.49*	-0.33		- .59**
Ponderosa pine							.42*		.50*	
Western larch			- .43*	- .48*	- .34	-0.36				
Engelmann spruce			- .35							
Preoutbreak:										
Grand fir										
Douglas-fir			.34		.41*	.40*	.32			
Ponderosa pine										
Western larch										
Engelmann spruce	- .37	0.42*								
Postoutbreak:	- .33				.49*		.68**		.56**	- .37
Grand fir	- .33				.50*		.67**		.57**	- .37
Douglas-fir			.64**	.59**	.65**		.46*	- .35		- .57**
Ponderosa pine							.44*		.51*	
Western larch			- .35	- .40		- .50*				
Engelmann spruce			- .34							

1/ Correlation coefficients with no asterisk are significant at the 10-percent probability level; 1 asterisk—5-percent level; 2 asterisks—1-percent level.

Table 9—Significant correlation coefficients (r) between environmental variables and stocking of regeneration, Wenaha-Tucannon Wilderness[1/]

Species and age class	Aspect	Slope	Basal area	Trees per acre	Crown closure	Ground cover	Litter	Logs	Litter and logs	Distance to seed tree
All regeneration:										-0.38
Grand fir	-0.42*									- .54**
Douglas-fir			0.42*		0.41*					
Ponderosa pine	- .39									
Western larch			- .47*	-0.57**	- .45*				-0.38	
Engelmann spruce			- .37		- .34					
Preoutbreak:										
Grand fir									- .34	
Douglas-fir			.34		.41*	0.40*	0.32			
Ponderosa pine										
Western larch										
Engelmann spruce	- .32									
Postoutbreak:										
Grand fir	- .55**						.34			
Douglas-fir			.37		.33			-0.35		
Ponderosa pine	- .41*								.33	
Western larch			- .36	- .46	- .38	- .59**		- .33	- .34	
Engelmann spruce			- .36	- .34						

1/ Correlation coefficients with no asterisk are significant at the 10-percent probability level; 1 asterisk—5-percent level; 2 asterisks—1-percent level.

Table 10—Dominant ground cover on subplots related to postoutbreak seedling establishment, Wenaha-Tucannon Wilderness

Item	Grass	Herbaceous	Woody perennial	Other
Number of subplots	82	120	99	5
Number of grand fir seedlings per subplot	.57	1.59	.99	5.8
Number of seedlings (all species) per subplot	1.23	2.51	1.69	6.8

Table 11—Overstory stand composition, by species, in a heavy tree mortality area, Wenaha-Tucannon Wilderness

Trees	Grand fir	Douglas-fir	Ponderosa pine	Western larch	Engelmann spruce	All species
			Trees per acre			
Alive	122.3	3.8	6.6	11.2	7.1	151.0
Dead	115.4	1.4	.4	.6	.5	118.3
Total	237.7	5.2	7.0	11.8	7.6	269.3
			Basal area (square feet per acre)			
Alive	56.6	.4	30.0	10.1	2.8	99.9
Dead	139.2	.6	1.1	.5	.3	141.7
Total	195.8	1.0	31.1	10.6	3.1	241.6

Overstory Composition and Mortality

Natural regeneration establishment after severe tree mortality is generally dependent on the condition and composition of the overstory. For example, overstory grand fir dominated both in trees per acre with 122 live and 115 dead, and in basal area, with 57 square feet per acre alive and 139 square feet per acre dead (table 11). This resulted in a corresponding dominance of the postoutbreak regeneration by grand fir. Ponderosa pine had a live basal area of 30 square feet per acre and dead basal area of 1 square foot per acre, indicating the scattered large pine have been an important seed source for the postoutbreak natural regeneration. Only a few small Douglas-fir per acre were present in the overstory within the study area, but postoutbreak regeneration was much greater than would be expected from this limited seed source. Apparently seed trees around the perimeter of the area provided much of the Douglas-fir seed for this regeneration.

Conclusions

The establishment of natural regeneration on Grizzly Bear Ridge after severe tree mortality due to the 1972-74 DFTM outbreak was moderate. Half the study plots were understocked based on a 60-percent stocking criterion. Distribution of regeneration was clumpy. Seedling density was adequate, however, as 67 percent of the plots had at least 400 trees per acre.

Seedling dominance, as indicated by species composition, age class, and height, has undergone some changes. Before the outbreak, regeneration was dominated by grand fir. Because that species suffered heavy defoliation and resulting mortality of both the overstory and regeneration, other species are increasing in number and size. Grand fir is still the dominant species as measured by subplot stocking and seedlings per acre, but the number of pine seedlings per acre has increased dramatically since the outbreak.

The tallest seedlings are the three species with the fastest juvenile height growth that were not severely defoliated by DFTM. Postoutbreak pine and larch regeneration, being less shade tolerant, have had more open growing conditions after many of the fir overstory trees were killed. This advantage may decline as grand fir regeneration grows and canopies begin to close.

The environmental conditions with obvious biological explanations, such as proximity of seed source and the relation of crown closure to shade-tolerant fir, related to regeneration success or failure. Observations on the plots indicated grasses inhibited regeneration establishment, as reported by Seidel and Head (1983) in a similar study. However, statistical analyses did not show a negative correlation for ground cover that included grass competition. One unexpected result was that litter showed a positive relation to regeneration density. The heavy tree mortality that occurred from 1972 to 1974 resulted in many downed snags 10 years later. The litter and slash accumulation from these snags was heavy on many plots, but this did not discourage regeneration. The material possibly provided shade and moisture-conserving mulch that sheltered seedlings from severe environmental effects during the critical first few years of growth. Similar relations have been found with litter and slash and natural regeneration after shelterwood cutting. Seedlings can become established in litter and slash seedbeds (Seidel 1979c).

What then is the long-term stand prognosis for this area, which suffered a severe natural perturbation a little over 10 years ago? It is too early to predict with certainty, but based on past management practices and present regeneration trends, the prior history and future scenario might be as follows: The stand, over 100 years ago, was mixed conifer, but dominated by pine. Fire prevention and control since the turn of the century have resulted in few or no ground fires and an increasing dominance by grand fir. As the fir grew, the canopy closed discouraging pine and larch regeneration. Grand fir is also a prime host of DFTM, and as available food supplies for the insect increased so did resident populations of DFTM. At some critical point, possibly because of site overstocking, lower resistance to foliage grazing by insects, and favorable climatic conditions, DFTM escaped from its natural controls and erupted into a short-term outbreak. The insect outstripped its food supply, causing heavy tree mortality, but the population crashed in the process.

Twelve years later the stand is again dominated by scattered, mature ponderosa pine, and pine regeneration is becoming an important component of the stand. But grand fir is the most prevalent species and unless a light wildfire burns in this part of the wilderness area, fir will slowly dominate and canopy closure will occur. In 70, 80, or 90 years the conditions of the site, trees, and insects will have come full circle and await the propitious combination of factors that will trigger the next DFTM outbreak and facilitate the demise of a grand fir-dominated stand in the Blue Mountains.

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Metric Equivalents

1 acre = 0.405 hectare
1 foot = 0.3048 meter
1 inch = 2.54 centimeters
1 mile = 1.61 kilometers
1 square foot = 0.0929 square meter
1 square foot per acre = 0.2296 square meter per hectare
1 tree per acre = 2.47 trees per hectare

Literature Cited

Day, Frank P.; Monk, Carl D. Vegetation patterns on a southern Appalachian watershed. Ecology. 55(5): 1064-1074; **1974.**

Reynolds, Charles; Jeffers, Nelson; Bousquet, Vincent; Stier, Roy. Reforestation surveys. *In:* Reports of the Pacific Northwest Seeding and Planting Committee on various recommended reforestation practices and techniques. Portland, OR: Western Forestry and Conservation Association; **1953:** 61-69.

Seidel, K.W. Regeneration in mixed conifer clearcuts in the Cascade Range and the Blue Mountains of eastern Oregon. Res. Pap. PNW-248. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1979a.** 24 p.

Seidel, K.W. Regeneration in mixed conifer shelterwood cuttings in the Cascade Range of eastern Oregon. Res. Pap. PNW-264. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1979b.** 29 p.

Seidel, K.W. Natural regeneration after shelterwood cutting in a grand fir-Shasta red fir stand in central Oregon. Res. Pap. PNW-259. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1979c.** 23 p.

Seidel, K.W.; Head, S.C. Regeneration in mixed conifer partial cuttings in the Blue Mountains of Oregon and Washington. Res. Pap. PNW-310. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1983.** 14 p.

Stein, William I. Regeneration outlook on BLM lands in the southern Oregon Cascades. Res. Pap. PNW-284. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1981.** 68 p.

Wickman, Boyd E. Tree mortality and top-kill related to defoliation by the Douglas-fir tussock moth in the Blue Mountains outbreak. Res. Pap. PNW-233. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1978a.** 47 p.

Wickman, Boyd E. A case study of a Douglas-fir tussock moth outbreak and stand conditions 10 years later. Res. Pap. PNW-244. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1978b.** 22 p.

Appendix

Data sources, collection methods, and summation procedures used for environmental and descriptive (independent) variables.

Aspect.—One of eight compass points measured on each subplot. The method proposed by Day and Monk (1974) was used to code the aspect, and the following values assigned to compass directions: N = 14; NE = 15; E = 11; SE = 7; S = 3; SW = 2; W = 6; NW = 10. Average coded value of the subplots was used in analyses.

Slope.—Percentage of slope of each subplot was measured with a clinometer and coded as follows: 0-9 percent = 0; 10-19 percent = 1; 20-29 percent = 2; etc. Average coded value of subplots was used.

Litter.—Percentage of each subplot covered with litter was estimated to the nearest 5 percent and averaged.

Litter and logs.—The percentage of each subplot covered with litter and logs was estimated to the nearest 5 percent and averaged.

Canopy closure.—Total vegetative cover present at 4 feet and above was estimated visually to the nearest tenth of the subplot area, coded in the same way as slope values, and averaged.

Ground cover.—Total vegetative cover present below 4 feet was estimated visually to the nearest tenth of the subplot area. Estimates for individual subplots were summed and a plot average was determined.

Dominant ground cover.—Vegetative cover was classed as the predominant one of three broad types: grass, herbaceous, or woody perennial. Separately, subplots dominated by grass and herbaceous plants or woody perennials were counted and computed as a percentage of the total subplots on the plot.

Seed source.—Distance to the nearest seed tree was judged as within 50 feet or over 50 feet in 100-foot classes. The nearest 16-inch d.b.h. or larger tree with a reasonably full crown was considered a source of seed. Trees smaller than 16 inches were noted if there was evidence they had borne seed. The species of the nearest seed tree was also recorded.

Overstory trees per acre.—The numbers of standing overstory trees (living and dead) and blown down trees were recorded on 0.02-acre plots at each of the sample points, averaged, and converted to a per-acre basis.

Overstory average diameter.—The diameters at breast height of living and dead standing trees and blown down trees on each 0.02-acre were measured to the nearest inch and averaged.

Overstory basal area.—Basal area was calculated for each tree on the 0.02-acre plots from its d.b.h., and an average basal area per acre was computed.

Wickman, B.E.; Seidel, K.W.; Starr, G. Lynn. Natural regeneration 10 years after a Douglas-fir tussock moth outbreak in northeastern Oregon. Res. Pap. PNW-RP-370. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; **1986.** 15 p.

A survey of natural regeneration 10 years after severe grand fir mortality caused by an outbreak of Douglas-fir tussock moth was conducted in the Wenaha-Tucannon Wilderness in the Blue Mountains of northeastern Oregon. Seedling stocking was only moderate, but seedling density was adequate where present. Grand fir is dominating both preoutbreak and postoutbreak regeneration, but ponderosa pine has increased substantially over preoutbreak levels. The largest seedlings are larch, spruce, and pine. These species have the fastest juvenile growth rate and also were not severely defoliated during the outbreak. Certain environmental factors affecting regeneration did not produce strong correlations other than some obvious relations like distance to nearest seed tree. There was a weak positive relation of regeneration density with the presence of litter. Given the past and present management regimes for this area, the pattern of gradual stand dominance by grand fir is the result of natural succession and lack of ground fires. Within a hundred years, history will probably repeat itself with a severe tussock moth outbreak that again reduces the grand fir component of the stand.

Keywords: Regeneration (stand), Douglas-fir tussock moth, *Orgyia pseudotsugata,* grand fir, *Abies grandis,* regeneration (natural), mixed stands, Blue Mountains-Oregon, Oregon (Blue Mountains), insect damage-forest.

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